Computer-task Testing of Rhesus Monkeys (*Macaca mulatta*) in the Social Milieu

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ABSTRACT. Previous research has demonstrated that a behavior and performance testing paradigm, in which rhesus monkeys (*Macaca mulatta*) manipulate a joystick to respond to computer-generated stimuli, provides environmental enrichment and supports the psychological well-being of captive research animals. The present study was designed to determine whether computer-task activity would be affected by pair-housing animals that had previously been tested only in their single-animal home cages. No differences were observed in productivity or performance levels as a function of housing condition, even when the animals were required to "self-identify" prior to performing each trial. The data indicate that cognitive challenge and control are as preferred by the animals as social opportunities, and that, together with comfort/health considerations, each must be addressed for the assurance of psychological well-being.

Key Words: Environmental enrichment; Psychological well-being; Apparatus; Social housing; Cognitive tasks.

INTRODUCTION

While scientists, administractors, and politicians struggle to find consensus on the meaning of "the psychological well-being of captive primates," clusters of relevant factors are emerging in the literature. Uniformly heralded among these contributive elements of enrichment and well-being is the dimension of social access — notwithstanding NOVAK and SUOMI's (1988) important caveats. Mere visual, auditory, and tactile availability of neighboring conspecifics can yield positive results even with singly caged animals, whereas social isolation of nonhuman primates has proven reliably to reap unfavorable social, physical, and cognitive consequences (CROSS & HARLOW, 1965; DAVENPORT et al., 1973; SUOMI, 1982; WASHBURN & RUMBAUGH, 1991). Pair- or group-housing of nonhuman primates permits expression of affiliative, playful, dominance, comforting, and other species-typical behaviors, and has proven effective in preventing depression, aggression, and a variety of similarly undesirable conduct (see, for example, FOX, 1986; HOPF & HERZOG, 1985; NOVAK, 1979; REINHARDT et al., 1987).

In addition to companionship, the aspects of comfort/health, challenge, and control have been discussed as important aspects of psychological well-being for nonhuman primates (WASHBURN & RUMBAUGH, 1992a) — and, apparently for human motivation as well (MALONE & LEPPER, 1987). We have described a psychological research tool and enrichment device, the Language Research Center's Computerized Test System (LRC-CTS, discussed below), and reported evidence that LRC-CTS access directly affects the dimensions of challenge, control, and comfort (WASHBURN & RUMBAUGH, 1992a, b). Rhesus monkeys exhibited frequent, stable, and preferential use of the test system — even after several years — and their task-related activity was shown to decrease the frequency of stereotypic or destructive behaviors. Further, extensive use of the LRC-CTS was argued to support the physical health and comfort of the research subjects. The present investigation was designed to determine how LRC-CTS use would affect, and be affected by, social access[1].

MATERIALS AND METHODS

EXPERIMENT 1

METHOD

Subjects: Two 10-yr-old male rhesus monkeys (*Macaca mulatta: Abel* and *Baker*), that have resided at the Sonny Carter Life Sciences Laboratory since 1987, were used as subjects. Each animal was highly proficient on each of the computerized tasks prior to this study; previous training and test histories have been documented elsewhere (e.g. RUMBAUGH et al., 1989). The animals were neither food nor water deprived and were free from any restraints within their home cages. Supplemental chow and fruit were provided daily to each animal. Prior to this study, the animals had been singly housed in close proximity with continual visual and auditory access to one another excepting brief and intermittent periods of isolation due to requirements of prior experimental designs; (WASHBURN & RUMBAUGH, 1991). The animals had also been pair-housed for brief periods prior to this study, although never with access to the LRC-CTS.

Apparatus: The present study required single housing (each animal within a 75 wide × 180 high × 90 cm deep cage) as well as paired housing conditions (within the same cages, but connected by an 86 long × 69 high × 48 cm wide tunnel). This apparatus can be seen in Figure 1.

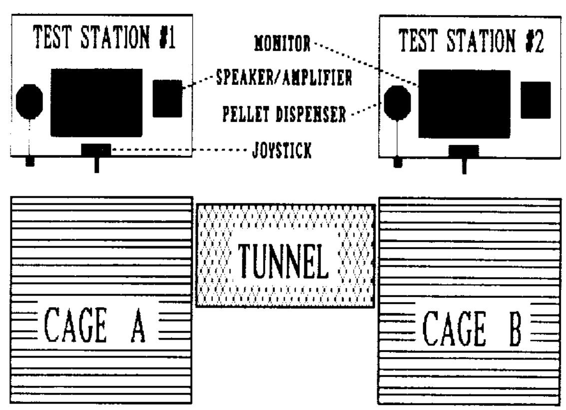

Fig. 1. Overhead diagram of two cages used in this experiment, connected by a tunnel to permit each monkey to access both cages and both test stations.

1) Other investigators (e.g. ANDREWS, 1993; HOPKINS) have tested socially housed animals using this test system, and have subsequently separated individuals from the group for testing; however, none have examined the effects of pairing animals that were trained under singly housed conditions.

Each animal was tested using a Language Research Center's Computerized Test System (LRC-CTS, described in detail by RUMBAUGH et al., 1989; WASHBURN & RUMBAUGH, 1992b). The LRC-CTS consisted of a battery of software tasks and the computer hardware required to administer them. Each LRC-CTS test station was comprised of a 386SX-compatible (16 MHz) computer, a color monitor, a joystick, an external speaker/amplifier, and a pellet dispenser. Computer-graphics stimuli were presented on the monitor, which was located outside of each animal's cage. To respond to the automated tasks, the animals manipulated a joystick by reaching through the mesh of their cages. Auditory feedback was presented via the speaker/amplifier, and 97-mg fruit-flavored chow pellets (Noyes) were dispensed following correct responses. All apparatus was protected within enclosures that permitted an animal direct access only to the joystick handle and the pellet cup. Wiring extended from each test station through conduit to the computer located in an adjacent room.

The animals' overt behavior in all conditions was observed directly or, when necessary, was videotaped for subsequent coding. Computer-task response accuracy, latency, and topography were recorded automatically by the computer.

Tasks: The LRC-CTS software battery consists of over 20 different computerized tasks. Each task permits subjects to respond to computer-generated stimuli by manipulating a joystick, which in turn controls the movements of a cursor on the computer screen. Nine tasks were arbitrarily selected for the purposes of this study: Select, Chase, Pursuit, Laser, Transfer index, Match-to-sample (MTS), Same-difference (SD), Detect, and Number. These tasks, which have been described in detail elsewhere (e.g. WASHBURN & RUMBAUGH, 1992b) represent computerized versions of many of the popular research paradigms in comparative and cognitive psychology. Two psychomotor tasks were used, on which subjects either had to "catch" a moving target (Chase) or "shoot at" a moving target (Laser). Pursuit was a pursuit tracking task that required subjects to maintain unbroken contact with a moving target for 0 to 12 s. Two-choice discrimination learning and reversal were studied with the Transfer index task, in which arbitrary pairs of randomly constructed stimuli are presented; subjects must determine across trials which stimulus must be touched to yield rewards. In the matching-to-sample task (MTS), subjects were required to select from two choices the stimulus that was identical to the sample stimulus. The sameness/difference (SD) task also required subjects to select from two choices either the matching stimulus or, if no stimulus matched the sample, a "D" (for different); however, a 0 to 40 s retention interval was used in the SD task so that it indexed memory rather than perception. A signal detection task (Detect) was also used, on which subjects had to respond upon the appearance of a target stimulus and ignore the presentation of numerous nontarget foils. On the Number task, subjects were presented with arrays of Arabic numerals and received on each trial the number of pellets corresponding to the numeral they selected. The tasks span a range from highly preferred (e.g. Number and Chase) to relatively nonpreferred (e.g. SD and Pursuit). All tasks were administered using the Select format, which permits the subjects to choose a task on which to work from a menu of familiar options.

Procedure: Each test day began when the computers and the ambient lights were started by a timer. Throughout the 16-hr test day, a menu of icons, each representing one of the tasks described above, was available on the computer screen. The animals worked ad lib, choosing both when to work and on which task to work.

Thrice each day, the animals' behaviors were observed and recorded on a checklist that consisted of the following categories: Task-related activity (manipulating the joystick, retrieving pellets, waiting at station through an inter-trial interval, etc), Cage-directed, Grooming, Stereotypy (rocking, pacing, etc), Resting/sleeping, and Drinking. Note that behaviors that are exclusively social (play, dominance-related, etc) were omitted from these records. Three randomly selected, 30-min time periods were designated each day to observe these characteristics. Within a given 30-min time period, each animal's behavior was coded every 30 sec. Thus, over 4,300 behavior samples were made at times across the 16-hr test day to determine activity patterns.

To determine the effects of single- vs pair-housing on performance and behavior, the animals were tested in an ABBA experimental design with each condition consisting of six test days. Each animal had continuous access to an individual LRC-CTS test station for each test day in the singly-housed condition. In the pair-housed condition (i.e. when the social access tunnel was in place), each animal could any time move about his own cage, the other animal's cage, and could use his own test station or the other animal's test station. Behavioral observations and LRC-CTS performance data were collected providing measures of behavior in both conditions. Testing lasted for a total of 24 days.

RESULTS

Performance data included trials per day, response time, and accuracy. Note that because it was impossible to determine which animal was working at each test station during the pair-housed condition, the data were analyzed by test station (Station 1 vs Station 2) rather than by animal (*Abel* vs *Baker*). Analysis of productivity revealed no difference in the number of trials performed at each test station, $F\ (1,\ 22) = .17$, $p > .05$. There was also no significant condition (single- vs pair-housing) effect, $F\ (1,\ 22) = 1.70$, $p > .05$; an average of 1633 trials were performed each day by each singly-housed animal, and 1713 trials/day/animal were recorded in the pair-housed condition. For both conditions, the average number of trials/task was comparable across tasks, and the distribution of trials/hour was similar for both test conditions. Similarly, analysis of the response time data yielded no significant difference between housing conditions, $F\ (1,\ 22) = 0.90$, $p > .05$ (see Fig. 2, top). The accuracy data analysis did yield a significant main effect for housing condition, $F\ (1,\ 22) = 7.58$, $p < .05$ (Fig. 2, bottom). However, this effect was found significantly to interact both with test station and task, $F\ (2,\ 44) = 4.81$, $p < .05$. Post hoc analysis revealed this interaction to reflect only a significant advantage for SD accuracy for Test Station No. 2 (*Baker*'s station when singly-housed) in the pair-housed condition (Mean SD accuracy on Test Station No. 2 = 71% by *Baker* alone and 77% by *Abel* and *Baker* together; HSD = 5%). Thus, the significant advantage for performance in the pair-housed condition is almost certainly an artifact of *Abel*'s efforts at both test stations, an interpretation further supported by the significant Test Station by condition interaction in the accuracy data, $F\ (1,\ 22) = 16.68$, $p < .05$ (*M* for singly-housed: *Abel* = 86%, *Baker* = 82%; *M* for pair-housed: Test Station No. 1 = 86%, Test Station No. 2 = 85%).

Observational data measuring behaviors in both conditions were averaged across animals. The percentage of time spent engaging in the selected behaviors was calculated. The most time-consuming activity in both conditions was that of video activity. In the singly-housed condition, 49% of the time spent was on video tasks. When pair-housed, the animals spent 47% of the time in task-related activity. These activity patterns, depicted in Figure 3, reveal no significant differences between the two housing conditions ($p > .05$).

Descriptively, the dominant scene during the pair-housed condition was of each animal working side-by-side at the two test stations. Frequently they would swap test locations,

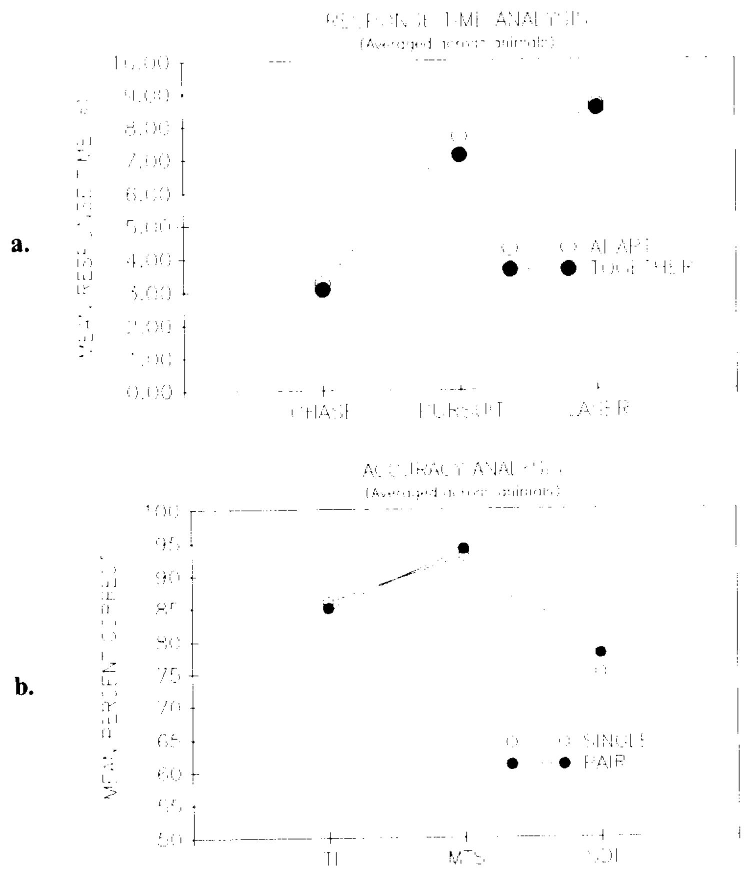

Fig. 2. Experiment 1 results. **a**: Mean response time as a function of task and housing condition; **b**: mean accuracy as a function of task and housing condition.

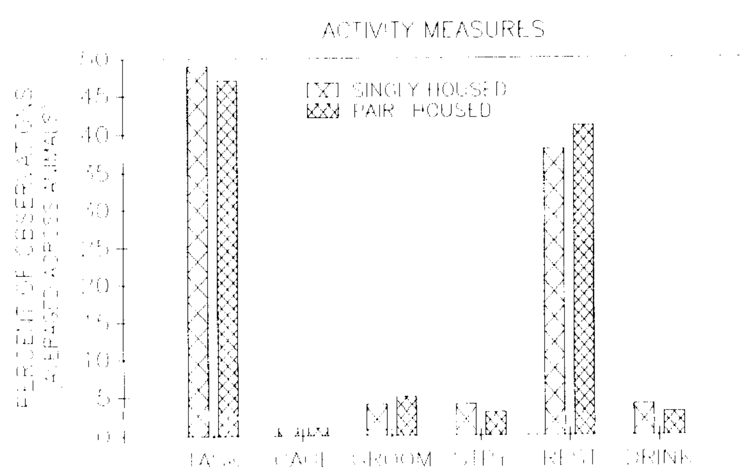

Fig. 3. Experiment 1 activity patterns as a function of housing condition.

and the animals were typically together during resting or grooming bouts. Play and dominance behavior were also observed during pair-housing, although not at frequencies that would substantially alter the overall activity patterns. At no time did either animal behave in such a way as to suggest the possibility of aggression, distress, or danger.

DISCUSSION

Pair-housing and social access clearly resulted in the expression of a variety of unique behaviors (grooming one's partner, changing test sites, resting together), but did not alter the levels of productivity or performance that characterize LRC-CTS use. The animals frequently choose to engage in challenging task-related activities rather than social behaviors, and showed no trend in task use across days of the experiment. At the same time, the monkeys' social behavior was typical and appropriate, and their general conduct was calm and affiliative. In summary, pair-housing the monkeys for LRC-CTS testing was nearly ideal, in that a corpus of performance data was obtained at comparable quality under conditions that clearly were comfortable and enriching for the monkeys.

Dominance (expressed through behaviors like mounting or presenting) also found expression through LRC-CTS use. Occasionally *Baker* (the dominant member of the pair) was observed to abandon his own test station and move to *Abel*'s if *Abel* was working on a preferred task such as the pellet-rich Number task. On these occasions, *Abel* typically moved voluntarily to *Baker*'s former test site and continued to work. *Abel* was never observed to displace *Baker* from a station. However, each animal was frequently observed to work undisturbed while the other animal rested or watched (and, of course, while the other animal worked), even when the two animals occupied the same cage space.

In all, the only drawback to testing the monkeys under pair-housed condition, as in this experiment, was the inability to disambiguate the responses of the two animals on the joystick tasks. Because one cannot determine from the data which animal was actually responding, all measures must be analyzed as a function of test station or amalgamated records. However, methods for identifying individual animals are being developed. Coding individual responses from videotape has been used, but is inefficient and labor intensive. Alternatively, ANDREWS (1994) described a transmitter chip that can be implanted subcutaneously into each monkey so as to provide for automated identification. In Experiment 2, we examined a behavioral means for facilitating animal identification in conjunction with LRC-CTS use.

EXPERIMENT 2

METHOD

The subjects and apparatus of Experiment 1 were used in this study. However, a new task was written which required subjects to "sign-in" or select an animal-specific stimulus prior to performing a trial on any other LRC-CTS task. This "signature" task began with the cursor presented in the middle of the screen. A large (5 × 2.5 cm), red, capital "B" was positioned randomly on the left side of the cursor, and a blue capital "A" of the same size was located in random position on the right side of the cursor. Each letter was surrounded by a box of corresponding color. The "A" was designated the correct stimulus for *Abel*'s responses, and the "B" was appropriate for *Baker*'s trials. Selection of the incorrect stimulus resulted in auditory feedback and a 15-s time-out period. Selection of the subject-appropriate stimulus resulted in one trial of an LRC-CTS task. Five of the tasks from Experiment 1 (Chase, Pursuit, Laser, TI, MTS, and SD) were used in this study. To ensure that each LRC-CTS task trial was finished by the animal that began it, each trial would end automatically and return to the signature screen whenever 5 sec elapsed with no manipulation of the joystick.

Each animal performed 3,000 trials on this task while singly-housed. Subsequently, the task was altered for an additional 3,000 singly-housed trials. On these trials, selection of either signature stimulus would result in one trial of an LRC-CTS task (no stimulus was incorrect or resulted in time-out). The purpose of this test was to determine whether the signature responses were reliable, or would easily be altered with removal of the consequences of error. Finally, the animals were tested for 10,000 trials each under pair-housed conditions. Here, the hope was that *Abel* would continue reliably to select the "A" prior to each trial and that *Baker* would continue to choose the "B" despite the fact that selection of either stimulus would result in an LRC-CTS trial. During this 10,000-trial testing, ten random probe periods were determined during which the accuracy of self-identification was observed and manually recorded for 100 trials. Thus, 1,000 observations per animal were obtained for evaluating the accuracy of self-identification under pair-housed conditions.

Results

The animals learned the "signature" discrimination quickly, and responded without error in the final 1,000 trials. Overall performance in the initial 3,000 trials and in the second block of 3,000 singly-housed trials exceeded 99% for both monkeys.

In the 1,000 probe trials during the 10,000 pair-housed trials, a total of only 6 errors were made (99.4%). These errors were distributed across the 10,000 trials (and the 6 days it took to obtain 10,000 trials/animal), so that the monkeys reliably chose the appropriate signature stimulus even when occasionally rewarded for incorrect responses.

As in Experiment 1, no significant differences were observed in productivity, response time, and accuracy levels in the pair-housed versus the singly-housed conditions [$F(1, 10) = 0.81$, 2.14, and 1.18, respectively; $p > .05$]. Moreover, these measures did not interact significantly with subject ($p > .05$). *Abel* did produce significantly shorter response times and significantly higher accuracy levels than did *Baker*, [$F(1, 10) = 6.22$ and 8.49, respectively; $p < .05$]. These differences, which are of little general interest other than illustrating the capability to disambituate the data, can be seen in Table 1.

Table 1. Mean performance and productivity levels, by animal, from Experiment 2.

Task/measure	*Abel*	*Baker*
Trials per day	1681	1657
Pellets per day	2009	1898
Chase response time	3.68 s	2.77 s
Pursuit response time	7.65 s	8.05 s
Pursuit accuracy (%)	96	89
Laser response time	6.41 s	9.89 s
Transfer index accuracy (%)	87	84
MTS accuracy (%)	96	92
Sameness/difference accuracy (%)	79	74

DISCUSSION

Two rhesus monkeys learned quickly to select a subject-appropriate stimulus in order to gain access to an LRC-CTS task trial, and continued to pick the appropriate stimulus even when either response would result in an LRC-CTS task trial. Consequently, each monkey accurately identified the trials on which he worked, and the data could be analyzed by animal. It is anticipated that this behavioral method of animal identification could prove reliable for even longer periods of testing, particularly if animals are provided periodic retraining underscoring the negative consequences of error. Additionally, more than two animals might come accurately to sign-on and use a single test station so long as the signature stimuli were sufficiently distinct and over-trained.

GENERAL DISCUSSION

In previous research, we argued that the LRC-CTS is a valuable enrichment device based on its relation to issues of challenge and control, and based on its compatibility with health and comfort concerns. We believed the LRC-CTS to be suitable for application with socially housed animals, based in part on the success of teaching the joystick-manipulation skills to animals within social groups; however, LRC-CTS use had not been demonstrated with singly caged animals moved into a social setting. Further, demonstrations of performance compromise by brief social isolation of singly-housed animals (WASHBURN & RUMBAUGH, 1991) generated questions about the consequences of pair-housing animals that are normally maintained separately. Would pairing individual animals result in elevated well-being and relatively improved performance? Would animals eschew task-related activity when presented with the opportunity for social behaviors? Would the monkeys balance affiliative needs and dominance issues with their motivation for challenge and control?

The results of these two experiments appear clearly to suggest that social opportunities, although undeniably important to well-being, are not the sine qua non of enrichment. Using the monkeys' preferences as the standard, the cognitive challenge and control afforded by the LRC-CTS competed favorably with social opportunity, suggesting that all three are necessary but not sufficient for psychological well-being. Bear in mind that these animals were not constrained to engage in task-related activity for the sake of food, as they were fully provisioned daily whether or not they worked. Notwithstanding, they continued to seek task-related activities even when other rewarding activities were available, and yet engaged in those other social behaviors frequently and appropriately.

In light of the relative novelty of direct social contact with a preferred cage-mate, and the years of experience with each of the tasks in the present experiment, the monkeys' LRC-CTS task-related activity patterns reported here are even more impressive. Of course, one might argue that this extensive history of testing and single-animal housing caused the animals to choose task-related activity over social behaviors; it remains for future studies to demonstrate that these findings generalize fully to animals raised in dramatically different contexts. Notwithstanding, it seems reasonable to conclude that the monkeys of the present study found familiar but challenging cognitive activities to be rewarding even when relatively novel social opportunities were afforded. The data also reflect the importance of challenge and control, along with companionship and comfort, as essential dimensions of enrichment and psychological well-being, and further support the applicability of the LRC-CTS as one means of effectively addressing each of these psychological needs.

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REFERENCES

ANDREWS, M. W., 1994. An automated identification system for use with computer-controlled tasks. *Behav. Res. Meth., Instruments, & Computers*, 26: 32 – 34.

CROSS, H. A. & H. F. HARLOW, 1965. Prolonged and progressive effects of partial isolation on the behavior of macaque monkeys. *J. Exp. Res. Personality*, 1: 39 – 49.

DAVENPORT, R. K., C. M. ROGERS, & D. M. RUMBAUGH, 1973. Long-term cognitive deficits in chimpanzees associated with early impoverished environments. *Develop. Psychol.*, 9: 343 – 347.

FOX, M. W., 1986. Handling, socialization, and caretaker effects. In: *Laboratory Animal Husbandry: Ethology, Welfare, and Experimental Variables*, M. FOX (ed.), SUNY Press, Albany, New York, pp. 71 – 83.

HOPF, S. & M. HERZOG, 1985. Onset of peer interactions in socially inexperienced squirrel monkeys. *Folia Primatol.*, 44: 121 – 128.

MALONE, T. W. & M. R. LEPPER, 1987. Making learning fun: a taxonomy of intrinsic motivations for learning. In: *Aptitude, Learning, and Instruction: III. Cognitive and Affective Process Analysis*, R. E. SNOW & M. J. FARR (eds.), Erlbaum, Hillsdale, New Jersey, pp. 223 – 253.

NOVAK, M. A., 1979. Social recovery of monkeys isolated for the first year of life: II. Long-term assessment. *Develop. Psychol.*, 15: 50 – 61.

——— & S. L. SUOMI, 1988. Psychological well-being of primates in captivity. *Amer. Psychologist*, 43: 765 – 773.

REINHARDT, V., D. COWLEY, S. EISELE, R. VERTEIN, & W. D. HOUSER, 1987. Pairing compatible female rhesus monkeys for cage enrichment has no negative impact on body weight. *Lab. Prim. Newsletter*, 27: 13 – 15.

RUMBAUGH, D. M., W. K. RICHARDSON, D. A. WASHBURN, E. S. SAVAGE-RUMBAUGH, & W. D. HOPKINS, 1989. Rhesus monkeys (*Macaca mulatta*), video tasks, and implications for stimulus-response spatial contiguity. *J. Comp. Psychol.*, 103: 32 – 38.

SUOMI, S. J., 1982. Abnormal behavior and primate models of psychopathology. In: *Primate Behavior*, J. L. FOBES & J. E. KING (eds.), Academic Press, New York, pp. 171 – 215.

WASHBURN, D. A. & D. M. RUMBAUGH, 1991. Impaired performance from brief social isolation of rhesus monkeys: a multiple video-task assessment. *J. Comp. Psychol.*, 105: 145 – 151.

——— & ———, 1992a. Investigations of rhesus monkey video-task performance: evidence for enrichment. *Contemp. Topics Lab. Anim. Sci.*, 31: 6 – 10.

——— & ———, 1992b. Testing primates with joystick-based automated apparatus: lessons from the Language Research Center's computerized test system. *Behav. Res. Meth., Instruments, & Computers*, 24: 157 – 164.

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